The Dominion Astrophysical Observatory
Victoria, B. C.

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THE 72-INCH REFLECTING TELESCOPE OF THE DOMINION ASTROPHYSICAL OBSERVATORY, VICTORIA, B. C.

By J. S. Plaskett

Introduction

The completion of this telescope marks what might be called the second epoch in the history of astronomical research in Canada. It is really an outgrowth and development of the work begun at the Dominion Astronomical Observatory at Ottawa in 1905 under the direction of its founder and the father of Canadian astronomical research, the late Dr. W. F. King, Chief Astronomer and Director.

The writer was entrusted by Dr. King with the development of the work with the 15-inch refractor at Ottawa, and when the stars within reach of useful spectroscopic observation with this aperture began to be seriously limited in number, the desirability of increased telescopic power was urged by him upon Dr. King. After the intervention of the usual stages present in getting Governmental interest in such a project to the point of action which, tho interesting, space prevents detailing, contracts were let in October, 1913, to the John A. Brashear Co. of Pittsburgh for the optical parts and to the Warner and Swasey Co. of Cleveland for the mechanical parts of a 72-inch reflecting telescope of the latest and best type.

The combined experience and talent of the Warner and Swasey Co. were given to the design of the mounting, conforming to the specifications drawn up by me after consultation with the users of large reflecting telescopes in America. Upwards of a year was spent in the design, about a year and a half in the construction and completion of the mounting at Cleveland and about six months in the dismounting, packing, shipping, and erection at Victoria. Three years after the contract was awarded, in October, 1916, the mounting was completely erected, ready for operation in its ob-

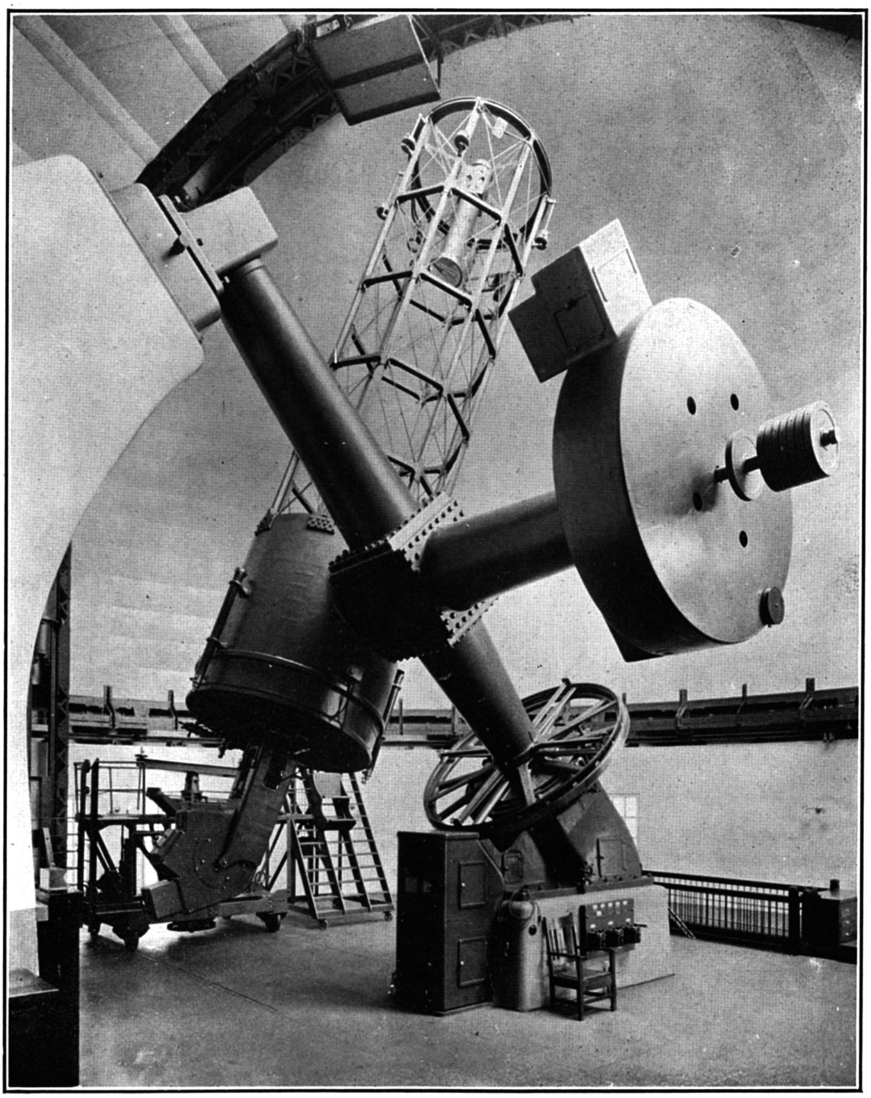
servatory on Observatory Hill, elevation 730 feet, about eight miles north of Victoria, B. C.

This was a remarkably short time for an undertaking of this magnitude, but unfortunately the optical parts were not ready until eighteen months later. The disk for the principal mirror was cast and annealed at the works of the St. Gobain Glass Co. at Charleroi in Belgium, was shipped from Antwerp only about a week before the declaration of war, arriving in Pittsburgh early in August, 1914. About a year was occupied in the rough and fine grinding and polishing and the mirror was ready for the figuring in August, 1915. Owing to delays connected with attempts to procure a large plane for testing the paraboloidal figure, no further work was done for a year. About a year and a half was occupied in the figuring, which was completed at the beginning of April in the current year. The mirror and other optical parts were shipped to Victoria, quickly installed in the already completed mounting, and regular observing was begun the first week in May.

That this telescope is in a Pacific Coast Observatory is due originally to the insertion, in one of the memorials to the Government urging the construction of the telescope, of a clause providing that it should be located at the place most suitable, astronomically, in Canada. This led to the investigation of numerous places, representative of different climatic conditions throughout the country, and to the selection of Victoria as by far the most suitable in the two important factors, low diurnal and seasonal range of temperature, and in "seeing" conditions. Observatory Hill was selected as the site and the land purchased in 1914, while building construction began in 1915. The observatory building, one residence for an astronomer and cottage for the engineer were completed in 1916, but, owing to war conditions, the office building and other residences which are necessary in the relatively inaccessible position of the observatory, are temporarily postponed.

The Mounting

The general design of the mounting, as will be well seen from the illustrations, is along the lines of the Melbourne 4-foot reflector and the Ann Arbor and remounted Crossley 3-foot instruments in having a long polar axis supported on separate bearings at the ends with the declination axis intermediate carrying the tube at one side of the axis and a housing containing the declination moving mechanism on the other.



This form of mounting was decided on in preference to the fork type of the 60-inch and the double fork of the 100-inch Mt. Wilson, as offering the advantages of reaching every part of the sky, and altho the displacement of the tube to one side of the center of motion requires a slightly larger dome, it is to my mind more than compensated for by the advantage above referred to and by the greater accessibility of the lower end of the tube for the attachment of spectrograph, etc. The Warner and Swasey Co. have evolved a design not only very workmanlike and efficient, but, as the illustrations show, well proportioned and pleasing in form.

The tube is in three sections: the central section to which the declination axis is attached, the lower section forming the mirror cell, and the upper skeleton section of the tube which serves to carry the Newtonian and Cassegrain mirrors and to support the plate holder for direct photography at the principal focus. The central section is a heavily ribbed steel casting 7 feet 4 inches outside diameter, weighing seven tons. It is 6 feet 1 inch high with a boss 41 inches in diameter, to which the declination axis is attached, and a flange at the bottom 7 feet 10 inches in diameter, to which the mirror cell is bolted. The latter is 18 inches deep, also a steel casting of the same diameter, with a corresponding flange at the top and radial spokes and concentric rings at the bottom which form the basis for the mirror support system, and for the rotating ring, 30 inches in diameter, to which the spectrograph is attached. The mirror support system is practically that adopted by Ritchey in the 60-inch, both bottom and edge supports being counterweighted to flexibly carry the weight of the mirror in any position of the telescope. The skeleton tube, which is 23 feet 4 inches long, 7 feet 4 inches in diameter, is an octagonal prism, built up of eight 3-inch I-beams extending uninterruptedly from top to bottom, where they are united by circular channel flanges. The tube is stiffened by four intermediate circumferential octagonal members built up of 3-inch I-beams, every intersection being reinforced by heavy cross-shaped pieces of steel plate inside and out, and at top and bottom by similar T-shaped pieces. In addition every one of the forty rectangular compartments of the built-up tube is further stiffened by diagonal tension rods which were screwed up, after the tube was riveted together, by means of right- and left-hand threads at the ends, to a tension of about 2000 pounds each. This design, which is a great improvement over previous forms of tube,

evidently ensures great stiffness with minimum weight. It is of comparatively inexpensive construction, as regular commercial shapes are used. The skeleton part of the tube weighs nearly two tons and, as the rods are always in tension, is exceptionally stiff and shows negligible flexure. The total weight of the complete tube including mirror, is about 15 tons.

The declination axis, which is 14½ feet long, 16 inches in diameter with a flange 41 inches in diameter, 4 inches thick, to which the boss on the central section of the tube is securely bolted, weighs nearly five tons and is rotated, and with it the tube, by a spur gear 8 feet in diameter keyed to the axis and contained in the circular housing at the outboard end.

The polar axis, as is readily seen, is in three sections, composed of a central cubical section thru which the declination axis passes and two conical end sections accurately faced off and firmly bolted together. These sections, the center piece and mirror cell of the tube, and the declination sleeve, are all steel castings of the highest quality, made and machined at the Bethlehem Steel Works, and are practically as free from blow holes and as homogeneous as forgings. The possibility of obtaining such large and perfect steel castings not only reduced the weight of the moving parts but has enabled a much more shapely and symmetrical form to be secured. The ends of the conical sections were bored out and steel forgings, which carry the inner sleeves of the ball-bearing system, were forced in. The total length of the polar axis is about 21 feet and its weight 9½ tons. After it was bolted together it was placed in a large lathe and all bearing surfaces turned true and concentric. It was never afterwards taken apart, thus ensuring perfectly true bearings.

The two supporting pedestals or pier heads of this polar axis are well shown in the illustrations. The north pier head is in two sections, the upper part carrying the north bearing of the axis being movable in altitude and azimuth by adjusting screws on the lower part which is bolted to the cement pier. The south pedestal of the shape shown is a substantial casting weighing seven tons and containing within it the quick motion mechanism in right ascension.

The driving clock is self-contained in the rectangular case to the north side of the south pedestal, from which it is entirely separate and supplied with adjusting screws to obtain the proper mesh of worm and worm wheel after the polar axis is adjusted. It is of the

regular Warner and Swasey type, about the same size as the 40-inch Yerkes clock, but is original in the method of connection to the worm, which is directly thru spur gears and without bevel gears, thus reducing danger of periodic error. A further original and ingenious arrangement is a pair of differentials in the main drive shaft, which alter the rate at will and supply slow motions in right ascension without the use of a cumbrous and heavy slow motion arm on the polar axis. The driving worm wheel is 9 feet in diameter, containing 720 teeth very accurately cut. This wheel, which weighs about two tons, is mounted on ball and ball-thrust bearing on the polar axis and can be moved with the slightest touch. In the tooth cutting process it was mounted on a long solid bed on its own bearings, a 42-inch circle, graduated on silver to half degrees on the very accurate Warner and Swasey dividing engine, was mounted concentrically and read by two microscopes. The teeth were cut one by one by a milling cutter moving the worm wheel between so that the graduations were bisected by the microscope cross wires. This was done three times around to remove any spring of the cutter, and the worm, which had been most carefully made and lapped, was then put in mesh with the worm wheel and rotated by a motor for about a week, rottenstone and oil being used as a smoothing and polishing material to remove any minor irregularities. As a result the telescope drives perfectly, not a trace of periodic error even with the 108-foot focus Cassegrain combination. This is a source of great satisfaction, as especial emphasis was laid on this feature. Nothing is more annoying and troublesome than the wandering back and forth of the image due to some period in the worm or driving train.

The bearings of polar and declination axes and of the worm wheel are ball bearings of the self-aligning type and have a remarkably low coefficient of friction. This telescope differs from all previous ones in avoiding the method of maintaining collimation by plain cylindrical bearings and reducing friction by rings of rollers, mercury flotation or other devices. To my mechanical mind I could not see why a modern ball or roller bearing whose surfaces are finished with mirror-like polish and high accuracy would not give as accurate collimation and greatly reduce the complexity, friction, and expense of the combined arrangement. The result has amply borne out my idea, for the motions are not only beautifully smooth and accurate and the following perfect, but the friction is

remarkably small. To turn the telescope on its bearings on the polar axis, all other sources of friction having been removed or allowed for, requires a pull of less than three pounds at the upper end of the tube, a leverage of 26 feet, and even at the lower end which is quite close to the axis the telescope can be readily moved with one hand. When it is realized that the moving parts weigh about 45 tons, it is evident that the friction is reduced to a minimum and tho no figures for other telescopes are available, I very much doubt whether any other form of friction relieving arrangement would do as well.

The providing of finely graduated circles for the telescope was never contemplated, as the experience of observers generally had shown that, besides the additional expense, the trouble and time required in reading them was so much greater than coarse circles as to more than compensate for the additional accuracy in setting. Consequently the attempt was made to combine the advantages of both by providing subdivisions of the usual spacing in the coarse divisions. In declination this is effected by a multiplying wheel driven by a pinion meshing in an internal gear in the rim of the declination circle. The drum of this wheel is divided into five-minute spaces and the telescope can hence be readily set to minutes of arc in declination. The reading in right ascension is given by means of a large divided circle nearly 9 feet in diameter, directly above the worm wheel, moving with it, and hence keeping sidereal time. This circle is loose on the hub of the worm wheel and can be readily pulled around by hand at the beginning of the night's work and set to the sidereal time against a fixed index on the meridian. Four index pointers on the polar axis 90° apart enable the telescope to be set without any mental arithmetic directly to the right ascension of the desired object, the pointer nearest the quick motion switch, from which it is never more than three or four feet away, being used. The circle is graduated to minutes of time, and intermediate settings to tenths can be readily estimated.

The telescope and dome are operated entirely by electric power, there being seven motors and a number of magnets and solenoids for the telescope, three motors for the dome and one for the silvering car. Direct current at 220 volts, this being much more suitable than alternating where motors have to be started, stopped and reversed so frequently, is provided by a motor generator set, power being obtained from the power lines of the British Columbia

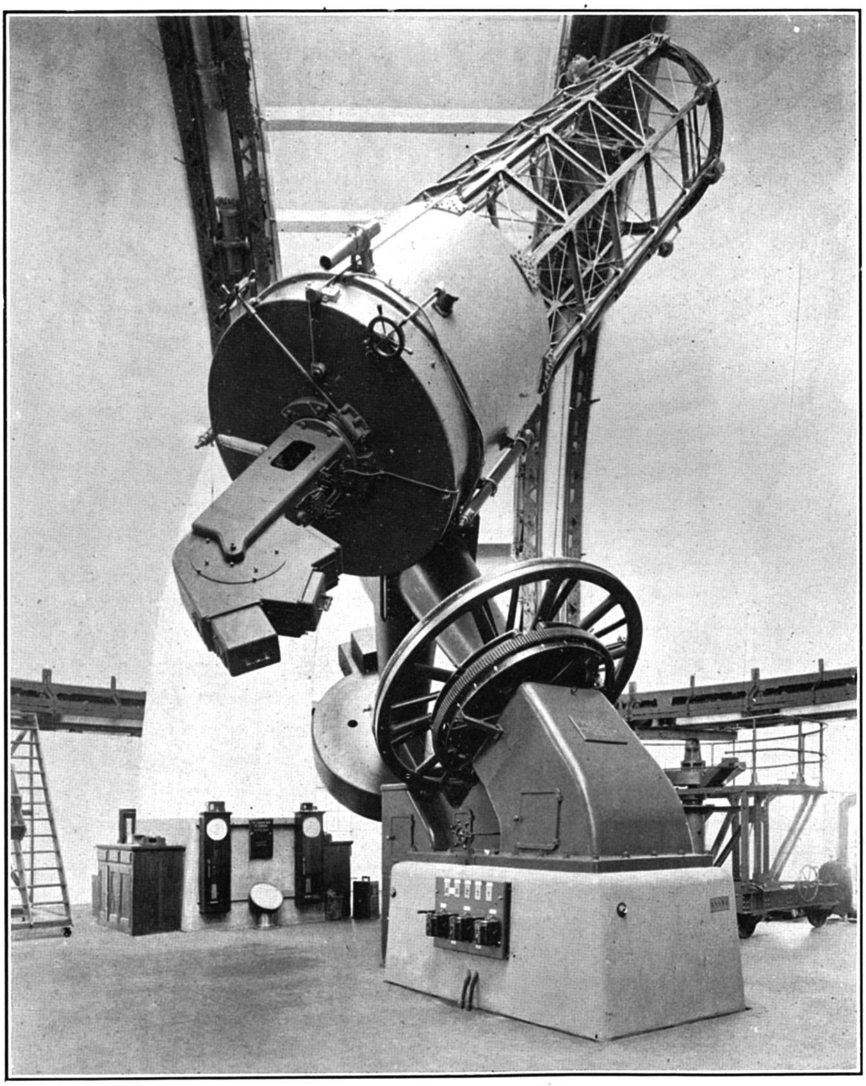


Fig. 3. The 72-Inch Reflecting Telescope
From the Southwest

Electric Railway Co. On each side of the south pier are duplicate operating boards, seen in the illustrations, the handles being from south to north—Dome Turning, Quick Motion in Declination, Quick Motion in Right Ascension respectively. Hence the telescope can be set and the dome revolved from either one of these boards from which the circles can be best seen and read. The push buttons control the illumination of the circles, the right ascension slow motion clamp and the declination quick and slow motion clamps.

Altho one person can readily operate the telescope, considerable time is saved by having an assistant to set the telescope by the quick motion handles to the tabular position, the speed in both coördinates being 45° per minute, when it is quickly clamped by the push button switches, and the observer at one of the finders brings the object to the center of the field by the slow motions operated by push buttons on a small portable aluminum switchboard which he carries with him.

The slow motions are exceedingly conveniently arranged, giving two speeds: a fine setting movement of 10 minutes of arc to the minute of time and a guiding movement one-twentieth of this speed, or one-half minute of arc to the minute of time. The setting motion is equivalent to one revolution of the telescope in 36 hours, the guiding to one revolution in 30 days. The push buttons on the portable boards, one at the upper and one at the lower end of the tube, are arranged in two sets exactly similar, the left hand buttons advancing in right ascension or moving to the north in declination, the right hand ones in the opposite direction, at the guiding rate. If it is desired to move the telescope more quickly all that is necessary is to continue holding down one of the guiding buttons and press an accelerating button just below, which gives the setting speed 20 times as fast. The mechanism in declination consists of the regular slow motion arm, the screw being driven by a motor thru worm reduction and a train of change gears operated by electro-magnet. In right ascension, as previously indicated, the slow motions are given by changing the rate of the worm-drive shaft by two sets of differential gears. By stopping either of the differential housings from revolving, by means of an electro-magnet operated by the push buttons, the rate is accelerated or retarded by the guiding speed and this action can be increased twenty-fold by driving the housings backwards by auxiliary motor.

Like the driving, these motions work beautifully smoothly and positively without backlash, and that the method of operation can not be much improved upon is evident when it is stated that in work with the spectrograph the average time required from the end of the exposure on the spectrum of one star to the beginning of that on the next is only about four minutes, which I think can hardly be beaten even with much smaller and lighter telescopes.

Space does not more than permit the mention of the many features about this mounting which are different from, and I believe an improvement upon, those previously employed. The construction of the skeleton tube, the dependence on ball bearings for both collimating and friction relieving functions, the avoidance of the right ascension slow motion arm and the use of differentials providing right ascension slow motions absolutely without backlash, the use of large steel castings giving a much lighter and at the same time stiffer and stronger mounting, the combined coarse-fine setting circles and arrangements for setting and guiding and finally, and perhaps most original of all, the mechanism at the upper end of the tube for changing from Cassegrain to Newtonian or Prime Focus or vice versa. As is well known, this has hitherto been accomplished by permanently fixing each of these mirrors with their attachments in separate extensions of the tube of the telescope and attaching and detaching these extensions. As these extensions in the case of the 72-inch would each weigh approximately 1500 pounds, the difficulty, delay, and trouble involved would be considerable. At Mr. Swasey's suggestion, to whom many of the original features of the telescope are due, it was decided to make the tube longer and change only the mirrors with their cells and necessary accessories. This has been beautifully worked out and instead of 1500 pounds, the maximum weight to be handled is less than 400 pounds, and this is so arranged that the change need not occupy more than ten or fifteen minutes and can be made entirely without risk or trouble of any kind.

I desire to express here my appreciation of the spirit in which the Warner and Swasey Co. have carried on this work. As soon as the contract was let, their one aim was to make the best mounting possible regardless of cost, and many features which were not called for by the specifications and which I would not think of asking for, but which they thought would increase the accuracy and convenience of operation of the telescope, were added to the

mounting. The workmanship throughout is of the highest grade and our experience in the operation of the telescope has not shown one single detail that we would wish changed. The accuracy of driving, the ease and quickness of setting, the smoothness, positiveness, and convenience of the guiding motions and the facility of changing from one form to another make this mounting a constant joy to operate. To Mr. Swasey, to whom we owe many of the original features, to Mr. Burrell, the Works Manager, to whose inventive and engineering skill the success of both telescope and dome is largely due, and to Mr. Walter Fecker, who made most of the detail drawings, our thanks are especially due. But every member of the firm was not only interested in and helped with the mounting, but joined in making my numerous visits to Cleveland not only interesting and profitable but very enjoyable as well.

The Optical Parts

The principal mirror, which is a beautiful piece of glass remarkably free from bubbles or other defects, has as finished dimensions a diameter of 73 inches, a thickness at the edge of 12 inches, with a central hole 10⅛ inches in diameter, and a weight of 4340 pounds. The finished surface has a diameter of 72.5 inches, 1841.5 mm., and a focal length of 361.4 inches, 9180 mm. The Cassegrain mirror has a diameter of 19.5 inches, a thickness of 3.25 inches and a focal length of nearly 10 feet. It is situated 86.2 inches inside the principal focus and the equivalent focal length of the combination is 108 feet, 32.92 metres. The Newtonian mirror has the same external dimensions as the Cassegrain, is circular, not elliptical in shape, as the small additional light to be gained, less than one per cent, did not make the increased difficulty of figuring and mounting worth while, and is situated 4 feet within the focus. Sleeves to attach the double slide plate holder are provided at two places on the side of the tube, that one being used which is most readily accessible from the observing platform.

A full set of oculars with the necessary adapters are provided for visual observations at the Primary, Newtonian, and Cassegrain focus. The range of focal lengths varies from ¼ inch to 4 inches, the longer foci being special wide angle, wide field oculars. For visual observation at the Cassegrain focus, an auxiliary reflecting telescope, screwing by a bayonet joint into the side of the spectrograph frame, enables visitors on the Saturday evening public

nights to observe without having to remove the spectrograph. This is a great convenience, as it can be attached or removed in a few seconds and spectroscopic observations need only be interrupted for the time the visitors are present, as the adjustments of the spectrograph are not disturbed.

There are three finders—two (one north, one south on the tube) of 4-inch aperture, 60-inch focus; and one long focus tubeless finder of 7-inch aperture and 30-feet focus, midway between the others and opposite the declination axis. As the field subtended by the reflecting slit jaws of the spectrograph is only about a minute of arc, it is occasionally necessary to use this finder to pick up the star on the slit, altho this can generally be done by the short focus finders.

As previously indicated, very considerable difficulty was experienced by the Brashear Co. in figuring the principal mirror. It was at first proposed to test the parabolic surface at the focus by the use of an auxiliary plane 55 inches in diameter, but the intervention of the war prevented the material for this plane being supplied by the St. Gobain Co. After the completion of the rough and fine grinding and polishing of the 72-inch, in August, 1915, nothing more was done for a year except fruitless attempts to obtain suitable material for this plane in America. When these failed, it was determined to make tests of the total parabolization by measurements of the radii of curvature of various zones of the surface, and to determine the general smoothness and regularity of the figure by means of a 33-inch plane, already in the possession of the Brashear Co.

In the figuring of the 72-inch surface, which was finally begun in August, 1916, unexpected difficulties, due chiefly to the presence of the large hole in the center, arose. As the full sized polishing tools used in the parabolizing had to be formed on the mirror itself, the polishing material had to be cut away over this opening. This made an irregular figure near the hole and there would also evidently be a tendency to over-correction around the edges of the opening. Much more local work than usual was hence necessary and the time of figuring was much increased. The surface was nearly finished twice, but in one case the presence of a few scratches which so far as optical effect was concerned were negligible, but which the Brashear Co. would not allow to remain, and in the other slight over-correction near the central opening, necessitated going back several stages in the work.

It was not until the end of March, 1918, that I was summoned to Pittsburgh to test the surface. These tests were carried out at the center of curvature both visually and photographically, supplemented by visual tests at the focus of the regularity and smoothness of the curve by aid of the 33-inch plane, which tho too small to determine the total parabolization, answered admirably in this other work. Visual tests by intersecting the converging pencils from an artificial star by a knife edge at eight different zones of the surface and photographic tests by the Hartmann method of extra focal exposures, for fifteen zones, one every two inches across the surface, agreed well in showing that the surface was very close to the theoretical form. When used with parallel light, the maximum deviation of the focus of any zone from the mean focus is only 0.25 mm., which is for a zone of 38 inches diameter. This is equivalent to a deviation of approximately one-eighth of a wave in the surface, which is hence practically perfect, and the mirror is undoubtedly one of the finest optical surfaces ever produced.

After the mirror was installed and its work with the spectrograph had shown that the figure of the Cassegrain combination was good, it was again tested at the principal focus by the Hartmann method, using a bright star as the source and photographing the images of circular apertures in a perforated zone plate placed on the mirror, at points inside and outside the focus. This was done under varying conditions of temperature, and the measures showed that only when the temperature had been nearly constant for several hours before the test did the figure at all approach that as tested at Pittsburgh. When, as in one case, the temperature in the dome had risen about 5° C. during the day and was falling after the mirror was exposed, the longitudinal aberration was nearly 3 mm. instead of 0.25, and did not decrease very much during the night. After a diurnal increase of only slightly over 1° C. during the day, the mirror showed very much better figure, the aberration being reduced to about 0.5 mm. This is an exceedingly satisfactory figure for practical purposes, as the irregularity of "seeing" will produce considerably more effect on the size of the images than aberrations of this magnitude. In every case the aberrations given were in the nature of under-corrections, focus at center longer than at edge, and even when the mirror was exposed to the cooler night air this under-correction only slowly diminished.

The evident remedy was to prevent overheating during the daytime, and altho Victoria was specially chosen on account of its relatively low daily temperature gradient, only about half that at other places tested, yet a change of 5° C., which is about the maximum in the dome, is much too great for the best results with the mirror. The obvious easy remedy would be, as had been done with the 60-inch, to surround the lower end of the tube with some non-conductor of heat and thus reduce the change inside, while, if this was not sufficient, to use as a last resort some kind of refrigerating apparatus.

I did not wish to have a canopy or any external removable covering, such as used with the 60-inch, partly for aesthetic reasons but chiefly on account of there being no convenient place to store such a huge affair, as this would necessarily be, when not in place. Consequently, as, in the lower enclosed section of the tube, there are about eleven tons of steel and two tons of glass which form very considerable reservoirs of heat, it seemed that the best plan would be to encase these permanently with quilted felt covers, externally over the cylindrical surface, internally between the back of the mirror and the sheet metal cover of the bottom of the cell, and all around the edge of the mirror between it and the cell. This left only the top of the center section of the tube unprotected and this is covered at the close of observing by an easily removable closely-fitting pad of three thicknesses of woolen blankets laid over light wooden boards placed across the opening.

The temperature change around the mirror was by this insulation reduced to between one-third and one-fourth of that in the dome and in consequence during the diurnal heating rarely rises more than 1° C. The performance of the mirror is thereby much improved and tho no Hartmann tests have been made since the cover was put on, direct photographs show very satisfactory star images, which we expect to improve as we obtain greater experience in focussing and guiding.

Altho the time of exposure of star spectra is not an entirely reliable guide as to quality of optical combination and seeing conditions, yet when it is stated that under average conditions well exposed spectra of stars of 7.0 photographic magnitude, the spectra having linear dispersion of 35A per mm. at Hγ, can be obtained in 25 minutes, it is evident there can not be much wrong with the surfaces.

The John A. Brashear Co. are to be congratulated on having produced such a splendid mirror under very difficult circumstances. The presence of the hole in the center of the mirror doubled, according to their estimate, both the difficulty and time of figuring. Towards the last, the tremendous pressure of war orders for optical parts, with the difficulty of getting suitable optical glass and the uncertainty as to how long it would take to complete the mirror, made the figuring, always a nervous strain, doubly trying, and I am exceedingly grateful to them for, and glad to take this opportunity of recording, their persistence with the work until their efforts were crowned with such notable success. Dr. Brashear himself, tho he has not taken an active part in their optical work for some time, was very much interested in the work on this surface and not only prepared all the tools but rough and fine ground and polished the mirror. Many of the methods of handling and testing are due to his ingenuity. The burden of the work, however, was taken by Mr. James B. McDowell, the Secretary and Manager of the company, ably assisted by his chief optician Mr. Fred Hagemann. It is to Mr. McDowell's skill and persistence in the face of great difficulties that the surface was finally brought to such a satisfactory finish. Much of the figuring was done by him personally, and altho at the last his other duties were too pressing to permit of this, he always tested after a working and decided on and directed Mr. Hagemann as to the next stage. The final touches were put on by Mr. Hagemann, who, by wonderful skill in local polishing, as it was not possible to get the true figure by large tools, gradually brought the surface to the accuracy given by the tests and at the same time maintained its smoothness and regularity of figure.

I am convinced after their experience and success with such a large and difficult piece of work no one need be uncertain as to the outcome and quality of any surface entrusted to them.

The Dome and Building

The dome was designed and constructed by the Warner and Swasey Co., and is the last word in the completeness and convenience of its operating facilities for a large reflecting telescope. It and the building which it surmounts, a good idea of whose form and proportions can be obtained from the accompanying photograph, are entirely of steel construction, having double sheet metal

walls throughout. An opening near the ground allows continuous circulation of air up the vertical walls, around the skirting and weather guarding between dome and building by an ingenious arrangement and out thru louvres at the top of the dome. This maintains the temperature much more equable than would otherwise be the case, as the inside temperature, owing to the considerable masses of material within, never gets as high as the shade temperature outside. At the same time, when the shutter, which has a clear opening of 15 feet extending 6 feet beyond the zenith, is opened, the steel construction permits a rapid equalization of inside and outside temperature.

The dome, which revolves on roller bearing wheels, and is driven by an electric motor once around in six minutes, is of very rigid construction but yet comparatively light. It is 66 feet in external diameter and its main structural features are the two main ribs which support the hemispherical walls and serve as a base to carry and operate the shutters, wind curtains and observing platform. These ribs, built up of double angle and thin web construction, are nearly 4 feet deep at the top and are so stiff that the weight of the polar axis, 9½ tons, when being hoisted, caused a deflection of less than one-eighth of an inch.

The shutters are double, each eight feet in width, and are opened and closed by electric motor. They are of the usual Warner and Swasey design and work smoothly and satisfactorily. Very efficient and well designed canvas wind curtains moving up from the bottom and down from the top of the shutter opening enable it to be limited to the width of the tube to prevent the wind from shaking the telescope. These are also motor operated and very positive and convenient in action.

The feature of the dome, which is most important in the operation of a reflecting telescope, is the observing platform. The platform of this dome, for which we are indebted to the engineering skill of Mr. Burrell, is a decided advance over previous designs and enables the upper end of the tube, when observing at the Prime or Newtonian foci, to be conveniently reached in any observing position. It is raised and lowered by electric motor, the operating handle being on the platform itself, at speeds varying at will from 1½ to 6 feet per minute. It moves on rails attached to the main ribs, being elevated and lowered by two sets of cables, one set serving for the direct lift and the other equalizing cables maintaining the platform horizontal in its path along the curved ribs. It is some

20 feet long and 4 feet wide, and at each side are movable wings extending inwards 6 feet, of circular shape on the sides facing each other. These are movable by hand wheels along the full length of the platform so that one can stand on one of these wings and move himself and it to the tube, the circular form of the side against the tube enabling the latter to be about three-fourths encircled by platform and wings and forming most convenient access for guiding, etc., in every required observing position. Counterweights moving in a continuation, on the main ribs, of the rails on which the platform runs serve to support the greater part of its weight, leaving considerably less work for the elevating motor. The platform is reached in any position by a substantial iron stairway, hinged to a stationary platform adjacent to the lowest position of the movable platform, and counterweighted so that when the observing platform is not in use this stairway can be pulled up against the roof of the dome entirely out of the way. The observing platform and wings are entirely surrounded by a firm railing about 30 inches high, making it quite safe to move around in the dark. Sections of this railing on the inside where they might interfere with the tube in some positions can be lifted out when necessary. But one can run up and down the stairs and move around on the platform without fear of falling off on the iron floor twenty to forty feet below.

Space does not permit a description of the silvering car, the extremely efficient and convenient means of removing, handling and replacing cell and mirror during resilvering, nor of the spectrograph and many other accessories of the telescope.

It is sufficient to say, after three months operation of the completed equipment, that it has fulfilled and more than fulfilled all expectations. It would have been only reasonable to expect in an instrument of such size, with so many new and untried features, that some defects would have shown themselves, some features of the design in which improvement could be made. That, within a week from the time the optical parts arrived in Victoria, the telescope was regularly engaged in making star spectra, that this work and other has gone on without interruption since, bears sufficient testimony to the care and skill used in design and construction of the mounting and dome, and to the eminently satisfactory character of the optical surfaces. Seeing conditions, which were tested only with a 4½-inch telescope, and whose behaviour under the in-

comparably severer test of a 72-inch aperture and 108-feet focus, it was quite impossible to predict, also exceed expectations, and the star image on the slit of the spectrograph is occasionally so small that the greater part of the light appears to be lost in the slit about one-third of a second in width. The accuracy, rapidity, and ease with which the telescope can be set on the star, the perfection with which it follows, and the quality of the images given make it a constant joy to operate, and I have yet to see any features in the design capable of improvement.

Unfortunately, owing to war conditions, the office building and residences for the astronomers are not built and the observatory is at present very insufficiently manned. Only Dr. Young and the writer are at present engaged in the scientific work and it is evident that it is impossible to even make observations, let alone discuss them, to anything approaching the capacity of this magnificent instrument.

It is hoped, as soon as conditions again become normal, that a sufficient staff to adequately use the instrument may be available In the meantime a beginning at the regular program of spectroscopic work will be made and other work not requiring much labor in the reductions may be undertaken.

Victoria, B. C., August, 1918.